Consumers Energy

A CMS Energy Company

Palisades Nuclear Plant
27780 Blue Star Memorial Highway
Covert, MI 49043

Tel: 616 764 2296
Fax: 616 764 2425

Thomas J. Palmisano
Site Vice President

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U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

DOCKET 50-255 - LICENSE DPR-20 - PALISADES PLANT
LICENSEE EVENT REPORT 99-004, "CONTROL ROD DRIVE SEAL HOUSING LEAKS AND CRACK INDICATIONS"

Licensee Event Report (LER) 99-004 is attached. The LER describes a condition where slight through-wall leakage was detected in two control rod drive (CRD) seal housings, part of the ASME Class 1 Primary Coolant System pressure boundary. Subsequent examination of all remaining seal housings was performed and additional crack indications were identified. This event is reportable in accordance with 10 CFR 50.73(a)(2)(ii).

The leaks were discovered during an inspection of reactor head components following reactor shutdown for the 1999 refueling outage. All defect indications were removed from each CRD seal housing prior to reinstallation.

SUMMARY OF COMMITMENTS

This letter contains no new commitments and no revisions to existing commitments.

Thomas J. Palmisano
Site Vice President

CC Administrator, Region III, USNRC
Project Manager, NRR, USNRC
NRC Resident Inspector - Palisades

Attachment

IE22

NRC FORM 366 (6-1998) U.S. NUCLEAR REGULATORY COMMISSION

LICENSEE EVENT REPORT (LER)

(See reverse for required number of digits/characters for each block)

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TITLE (4)

CONTROL ROD DRIVE SEAL HOUSING LEAKS AND CRACK INDICATIONS

EVENT DATE (5)			LER NUMBER (6)			REPORT DATE (7)			OTHER FACILITIES INVOLVED (8)	
MONTH	DAY	YEAR	YEAR	SEQUENTIAL NUMBER	REVISION NUMBER	MONTH	DAY	YEAR	FACILITY NAME	DOCKET NUMBER
										05000
10	16	1999	1999 --	004 --	00			1999	FACILITY NAME	DOCKET NUMBER 05000

OPERATING MODE (9): N

POWER LEVEL (10): 000

THIS REPORT IS SUBMITTED PURSUANT TO THE REQUIREMENTS OF 10 CFR §: (Check one or more) (11)

	20.2201(b)		20.2203(a)(2)(v)		50.73(a)(2)(i)		50.73(a)(2)(viii)
	20.2203(a)(1)		20.2203(a)(3)(i)	X	50.73(a)(2)(ii)		50.73(a)(2)(x)
	20.2203(a)(2)(i)		20.2203(a)(3)(ii)		50.73(a)(2)(iii)		73.71
	20.2203(a)(2)(ii)		20.2203(a)(4)		50.73(a)(2)(iv)		OTHER
	20.2203(a)(2)(iii)		50.36(c)(1)		50.73(a)(2)(v)		Specify in Abstract below or in NRC Form 366A
	20.2203(a)(2)(iv)		50.36(c)(2)		50.73(a)(2)(vii)		

LICENSEE CONTACT FOR THIS LER (12)

NAME	TELEPHONE NUMBER (Include Area Code)
Robert A. Vincent, Licensing Support Supervisor	(616) 764-2559

COMPLETE ONE LINE FOR EACH COMPONENT FAILURE DESCRIBED IN THIS REPORT (13)

CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE		CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE
B	AA	DRIV	C490	Y						

SUPPLEMENTAL REPORT EXPECTED (14)

				EXPECTED SUBMISSION DATE (15)	M	DAY	YEAR
	YES (If yes, complete EXPECTED SUBMISSION DATE).	X	NO				

ABSTRACT (Limit to 1400 spaces, i.e., approximately 15 single-spaced typewritten lines) (16)

On October 16, 1999, following shutdown of the reactor for the 1999 refueling outage, inspection of reactor head components revealed the presence of moisture and/or boric acid deposits on the exterior surfaces of three Control Rod Drive (CRD) [DRIV] seal housings. The CRD seal housing assemblies comprise a portion of the ASME Class 1 Primary Coolant System [AB] pressure boundary. The affected seal housings were removed when plant conditions permitted, and on November 2, 1999, two of the three were determined to have small through-wall cracks. All 45 seal housings were ultimately removed from the head and inspected utilizing visual, dye penetrant and eddy current examination techniques. The inspections revealed that 30 of the 45 seal housing assemblies contained small circumferential cracks. Three seal housing tubes also contained small axial cracks. Examination of spare housings showed similar crack indications. The cracking has been determined to be transgranular stress corrosion cracking, probably resulting from inadequate post-weld heat treatment which left residual stresses of sufficient magnitude to support cracking. 45 seal housing assemblies were repaired as necessary for reuse during the next operating cycle.

EVENT DESCRIPTION

On October 16, 1999, following reactor shutdown for the 1999 refueling outage, an inspection of reactor head components revealed the presence of moisture and/or boric acid deposits on the exterior surfaces of Control Rod Drive Mechanism (CRDM) seal housings in the CRD-10, CRD-26 and CRD-44 locations. These seal housings were removed from the reactor head when plant conditions permitted. On November 2, 1999, it was determined through visual (VT) and dye penetrant (PT) examinations that all three housings contained cracks in the vicinity of the "J" welds attaching the housing tubes to their autoclave flanges. The cracks in the housings from the CRD-10 and CRD-44 locations were apparently through-wall. Seven additional seal housing assemblies which had been removed for other reasons were also examined. Six of the seven additional seal housings also showed crack indications on the inside diameter (ID) of the seal housing tube under one or more examinations utilizing VT, PT or eddy current examination.

Based on the inspection results, the scope of the inspection was progressively broadened and all 45 CRDM seal housings were removed from the reactor head. The inside diameters of each seal housing tube and tool access tube were examined using VT, PT and eddy current inspection techniques in the vicinity of their "J" welds. The examinations revealed that 30 of the 45 seal housing assemblies contained small circumferential cracks in the vicinity of the "J" welds. Three housings also contained small axial cracks in the seal housing tube walls. In addition, several tool access tube upper flange areas were examined to determine if the cracking was limited to the seal housings.

ANALYSIS OF EVENT

Each control rod at Palisades is driven by an electric motor through a drive shaft and bevel gears which engage a rack assembly coupled to the control rod. The drive shaft is offset from and parallel to the axis of its associated control rod. Figure 1 provides a sketch of the CRD seal housing assembly configuration. The primary coolant pressure boundary is provided by a rotating mechanical seal located at the top of the seal housing tube. The lower flange of the seal housing (autoclave flange) is fastened to the support tube with the autoclave nut. The lower region of the seal housing below the mechanical seal provides the primary coolant pressure boundary. The drive motor and clutch assembly mount on the atmospheric side of the mechanical seal at the top of the seal housing. The tool access tube penetrates the autoclave flange directly above the rack assembly. The tool access tube provides access for coupling and uncoupling rods, and is closed with a blank flange when the primary coolant system is filled.

Previous Experience With CRD Seal Housing Cracking - Cracking of CRD seal housings at Palisades was initially observed in 1986 when a through-wall leak was identified in CRD-25. Inspections (visual and PT) of all 45 housings over the following several years identified thirteen other housings with circumferential and/or axial cracking in the vicinity of the "J" weld. Evaluations by Consumers Power and ABB Combustion Engineering identified the cracking as transgranular stress corrosion cracking (TGSCC). This event was reported in LER 86-40, LER 86-40, Rev 1, LER 86-40, Rev 2 and LER 86-40, Rev 3.

In response to this problem, ABB Combustion Engineering modified the CRD seal housing design by changing the material of fabrication from Type 304SS to Type 347SS. Other minor design changes were also made to improve seal cooling and to reduce stresses in the housing wall. Type 347SS was chosen as the replacement material since it can be given a post weld stress relief heat treatment without inducing sensitization. Sensitization makes stainless steels subject to intergranular stress corrosion cracking and pitting in oxygenated environments. The stress relief heat treatment was intended to reduce weld residual stresses near the "J" welds in the seal housing and tool access tubes, thereby reducing the probability for initiating TGSCC near the welds. The modified seal housings were installed in all 45 CRD locations during outages between 1990 and 1995. Selected seal housings have been inspected during each refueling outage since 1995 to monitor performance.

In December 1998, during an inspection of reactor vessel head components during hot shutdown, minor leakage was discovered in the CRD-2 seal housing. The housing was replaced with a spare Type 304SS housing, and was subsequently given a detailed metallographic examination. The cracking in CRD-2 was determined to be TGSCC and circumferentially oriented, similar to the cracking observed in the old Type 304SS housings. Cracking was not observed in the tool access tube, but a detailed metallographic examination was not performed in that area. The housing crack appeared to initiate in the vicinity of an inside surface repair weld which had been heavily ground. Review of manufacturing records indicated that this particular housing had required two cycles of weld repair and three cycles of post weld heat treatment. The metallurgist performing the evaluation noted the presence of some short intergranular cracks in the repair weld heat affected zone which indicated the presence of sensitization. This would not be expected in a housing given a proper post weld heat treatment. Detailed surface chemistry examinations on the crack faces revealed no contaminants which could be assigned as a cause of cracking. The housing had been in service since 1992. It was concluded that the extensive repair history of the CRD-2 seal housing caused it to be an outlier relative to the other Type 347SS housings installed on the reactor, and the cracking was, therefore, an isolated occurrence. This event was reported in LER 98-014.

Transgranular stress corrosion cracking has been observed in all common austenitic grades of stainless steel including Type 304 and Type 347. Cracking requires the simultaneous presence of oxygen and chlorides in water, and tensile stress. Cracking is accelerated at elevated temperatures. While there has been some work relating required oxygen levels and chloride levels to cracking, the threshold level of chlorides required to be present has not been established. Moderate tensile stress levels are required, but the threshold level required to cause cracking is strongly dependent on the environment. A rule of thumb in moderately aggressive environments is that stress levels would have to be a significant fraction of the yield stress to cause cracking. The environment and stress conditions in the CRD seal housings are discussed below.

Seal Housing Operating Environment - The CRD seal housing is exposed to a stagnant, aerated environment immediately after plant fill and during some period of time after Primary Coolant System pressurization and heatup. The seal housing is the most elevated portion of the CRDM and traps air during plant fill. The Palisades seal housing is not designed to be vented during the fill evolution. Since this region provides a dead end space, the air is forced into solution in the housing which can lead to extremely high dissolved oxygen levels. These high levels persist during operation until they decrease by diffusion out of the CRDM or by leakage out past the CRD mechanical seal. Air in the tool access tube can only be removed by diffusion. The typical operating temperature in the housing is estimated to be 230°F. In certain regions of the reactor head, the operating temperature in the housing may be somewhat higher due to variations in head cooling air flow distribution. These temperatures are sufficient for cracking to occur.

Chloride levels in the CRD seal housing during normal operation can not be determined directly, but they can be inferred. Normal levels of primary water chlorides at Palisades are very low, about 4-5 ppb. Concentrations in the housing could be somewhat higher than this value due to normal chloride leaching from stainless steel surfaces, chlorides leaching from nearby gasket materials, and/or contamination from dye penetrant examination materials, but they are not expected to be on the order of many ppms based on the following:

a. Recent laboratory testing of leachable chlorides from CRD housing flexitallic gaskets at elevated temperatures (212°F and 247°F) showed consistent results of less than 1 ppm leachable chloride.

b. Compounds used in the dye penetrant examination process (penetrant, developer and cleaner) include chlorinated hydrocarbons with chloride levels ranging between 20 ppm and 109 ppm. Although surfaces are cleaned after each examination, it is possible to leave some trace amounts of residue following the process. Subsequent dilution, however, would result in much lower final levels in solution as a contaminant.

Since the environment is stagnant, total chloride levels are expected to increase gradually with time during operation due to leaching. It is plausible that the stagnant housing area could see levels of chlorides increased significantly above normal primary coolant levels. This, combined with extremely high dissolved oxygen levels, could make the environment moderately aggressive for TGSCC.

Stress - CRD seal housing circumferential cracks are clearly associated with residual stresses near the "J" welds. Most circumferential cracks lie within 3/8 inch of the flange face in an area where "J" weld residual stresses could be significant. Axial cracking has been observed about one inch from the flange face in a region that would not be expected to be highly stressed by "J" weld residual stresses. The source of stress for axial cracking in the type 347SS housings is considered to be a residual stress from post weld heat treatment (PWHT), as discussed below.

A review of ABB/CE manufacturing records indicates that the "J" weld areas of both the seal housing and tool access tubes were given PWHT by induction heating. Records indicate that a heating coil about 2 inches long was inserted into the seal housing tube and tool access tube for PWHT in the temperature range of 1650°F to 1800°F for four hours. The housing and access tubes were given the PWHT sequentially. It is hypothesized that the PWHT could have created a large radial temperature gradient through the housing tube wall, since heating is most intense on the ID surface near the coil, and the housing outside diameter (OD) is cooled by the relatively large heat sink effect of the flange. If housing ID stresses exceeded yield during PWHT, large tensile stresses (both axial and circumferential) could have been induced in the housing ID surface and to some depth after cool down. This is a similar effect to that of Induction Heating Stress Improvement treatments commonly applied to BWR piping by heating with an external coil to induce compressive stresses on the pipe ID surface.

It is concluded that the stresses in the vicinity of the "J" weld have two contributors: the very localized "J" weld residual stresses that were apparently not relieved adequately by the PWHT; and the PWHT-induced axial and circumferential tensile stresses that could extend upwards of two inches from the flange face. It is these latter stresses that are the likely driving force for the axial cracks observed in three seal housings. It is further concluded that PWHT-induced stresses should be smaller in the tool access tube, since radial thermal (and stress) gradients are expected to be smaller in this relatively thin wall tube. This is consistent with the observation that few, if any, axial indications with any reported depth have occurred in the tool access tubes.

Material Effects - A review of the literature indicates that TGSCC can occur in any of the austenitic stainless steels, whether fully solution annealed or sensitized. While there is some evidence that sensitized materials will crack sooner than annealed materials, sensitization is not required for TGSCC, unlike typical IGSCC observed in BWR's.

There is some evidence that TGSCC initiates after an "incubation" period during which no cracking is observed. For example, cracking in a Type 348SS CRD mechanism housing at another plant was observed to have incubated for approximately ten years before the initiation of cracking by TGSCC. Surfaces that cracked were relatively undisturbed surfaces near a weld overlay, and the incubation time was long. It is believed that incubation times are reduced dramatically if surface cold work (such as by grinding) or repair welds that have not been effectively PWHT'd, are present. For this reason, it is believed that the crack in CRD-02 at Palisades in December 1998 probably initiated during or just after the first cycle of operation. Further, the distribution in cracking times for the various CRD seal housings at Palisades is probably as dependent on surface conditions of the metal (e.g., roughness, tool marks, etc) near each "J" weld as they are on any other variable (e.g. temperature, oxygen level, material chemistry, etc).

A literature review was conducted to provide a conservative estimate of the TGSCC crack initiation time in the repaired housings. Conservative data from 572°F tests in water containing very high chlorides (100-1000 ppm) with oxygen were used to estimate crack initiation times on as-machined sample surfaces at the CRD seal housing temperature which was conservatively assumed to be 300°F. The results of this estimation indicate that for these conditions the minimum crack initiation time to be expected is 1.68 Effective Full Power Years (EFPY). This estimate is consistent with the fact that no leaking housing has been observed at Palisades with less than 3 ½ fuel cycles of service life.

Repair Activities - All known defects in the CRD seal housing assemblies being installed were removed by flap wheel polishing. The affected regions were not only restored to a defect-free condition as verified by VT, PT and eddy current testing, but they were also given a polished surface which would provide significantly fewer corrosion initiation sites than the normal machine surface of a seal housing ID. This polishing is expected to significantly extend the incubation period required for initiation of TGSCC. This was substantiated by comparing crack propagation test results from material samples repaired by flap wheel polishing with test results from a machined surface. The polished surfaces showed significantly longer crack initiation times. All installed CRD seal housings, with the exception of the three brand new housings purchased prior to the refueling outage, were given a polished surface in the vicinity of their "J" welds.

The repair criteria utilized for this work was developed to assure that all installed housings will have sufficient wall thickness such that even if corrosion were to recur, the predicted remaining wall thickness at the end of the operating cycle will continue to meet code requirements for minimum wall thickness.

Future Activities - While this cracking phenomenon is judged to have minimal safety significance, it has significant implications for plant availability. Investigation into alternate seal housing designs and/or materials is being conducted to identify practical alternatives for reducing the potential for cracking to recur. The CRD seal housings which have been installed for the upcoming operating cycle have not yet been found acceptable for more than one operating cycle. It has not yet been determined whether the seal housings to be utilized after the next refueling outage (currently scheduled for 2001) will be the existing housings, if they can be verified to be in an acceptable condition, or whether housings with additional repairs or appropriate replacements will be installed.

It should be noted that the cracked seal housings from locations CRD-10 and CRD-44 are currently undergoing destructive metallographic examination. This examination is being performed to provide additional corroboration of the root cause as discussed in this LER.

SAFETY SIGNIFICANCE

This event is of minimal safety significance. Total failure of a seal housing due to this phenomenon without prior detection is not considered credible. The worst potential significance of total failure, however, would be a small break loss of coolant accident (SBLOCA). SBLOCA is an analyzed event that has been demonstrated to result in acceptable consequences. Failure of a seal housing could not result in a rod ejection.

CAUSE OF THE EVENT

The apparent cause of this condition is transgranular stress corrosion cracking (TGSCC) in the environment present in the seal housings, combined with an inadequate post

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weld heat treatment of the seal housing assemblies during manufacture which left residual stresses of sufficient magnitude to promote the initiation of cracking.

CORRECTIVE ACTIONS

Corrective Actions Taken:

1. All seal housings in service during the last operating cycle were examined using some combination of visual, dye penetrant, eddy current and/or ultrasonic inspection techniques. The indications noted were characterized as to nature and extent.

2. Repairs were completed such that all 45 housings installed on the reactor head for the next operating cycle are free of defects and in full compliance with code requirements.

3. All reused seal housings and tool access tubes have been polished in the vicinity of their "J" welds to eliminate or mitigate crack initiation sites.

Corrective Actions Remaining:

None

PREVIOUS LERs

LER 86-40	01/16/87	Cracking of Control Rod Drive Seal Housing
LER 86-40, Rev 1	02/16/87	Cracking of Control Rod Drive Seal Housing
LER 86-40, Rev 2	04/16/87	Cracking of Control Rod Drive Seal Housing
LER 86-40, Rev 3	12/02/87	Cracking of Control Rod Drive Seal Housing
LER 98-14	01/26/99	Control Rod Drive Seal Housing Leak

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FIGURE 1

Control Rod Drive Seal Housing